

HEAT EXCHANGER TUBE

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I have now surprisingly found that better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production

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coolant.

The projections are preferably dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

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Preferably the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results obtained by the inventor at the time of preparation of this specification are achieved when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

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For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

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5 The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy and the tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld, with the
10 weld seam running along one edge of the tube which joins the two major walls, after the tube has been flattened. However, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be

reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the tube/header tank joint area.

- 5 The invention also provides a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins, wherein each of the tubes has a flattened cross-section with two major opposing walls and internal projections on the major
10 opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections
15 amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed
20 through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is
25 maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between
30 the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

Figure	Figure	Figure	Figure	Figure	Figure	Figure	Figure	Figure	Figure
Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 10

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coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16, and the heat of the coolant in the tubes 14 is given up to the air passing through the fins.

Figure 2 shows an enlarged cross sectional view through a tube 14. The tube is formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.

The tube 14 shown in Figure 2 has a smooth internal bore 24. If coolant flows along a tube 14 with a smooth internal bore, the coolant flow along the tube tends to be laminar or streamline flow. In this case there will be a region at the centre of the flow (indicated in dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube, and this region of coolant is therefore insulated from the heat exchange taking place at the tube walls by the body of coolant between the region and the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which does enhance mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28, and whilst passing through the tube will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V-IV,V from Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tube 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with

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indentations on the upper (as seen in the figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend
5 along a line which makes an angle of approximately α to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of α to that of the indentations on the upper face. The preferred range for such
10 angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the
15 upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and 9 where the arrows
20 show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant
25 flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or
30 arrangement of indentations, but it is preferable that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection. However since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection whereupon diversion and therefore coolant mixing will take place again.

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally (as shown in Figure 8) and also perpendicularly (as shown in Figure 9) to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

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- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- 10 • simplifying manufacture and reducing tooling costs
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger
15 vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm², and the area of the tube covered by indentations can amount to about 2.5% of the total tube
20 surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through
25 computer modelling.

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